

Independent Evaluation of Frozen Precipitation from WRF and PRISM in the Olympic Mountains

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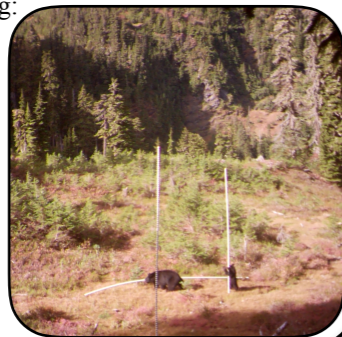
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Introduction & Driving Questions

Estimates of precipitation from the Weather Research and Forecasting (WRF) Model and the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) are widely used in complex terrain to obtain spatially distributed precipitation data. We evaluated both WRF (4/3 km) and PRISM's (800-m annual climatology) ability to estimate frozen precipitation using the hydrologic model Structure for Unifying Multiple Modeling Alternatives (SUMMA) and a unique set of spatiotemporal snow depth and snow water equivalent (SWE) observations collected for the Olympic Mountain Experiment (OLYMPEX) ground validation campaign during water year 2016.

Specifically we focus on the following:

1. Is PRISM or WRF better able to simulate frozen precipitation over an entire water year?
2. Is PRISM or WRF better at simulating snow during the OLYMPEX intensive observing period?
3. Are errors in WRF or PRISM spatially dependent?



Study Area

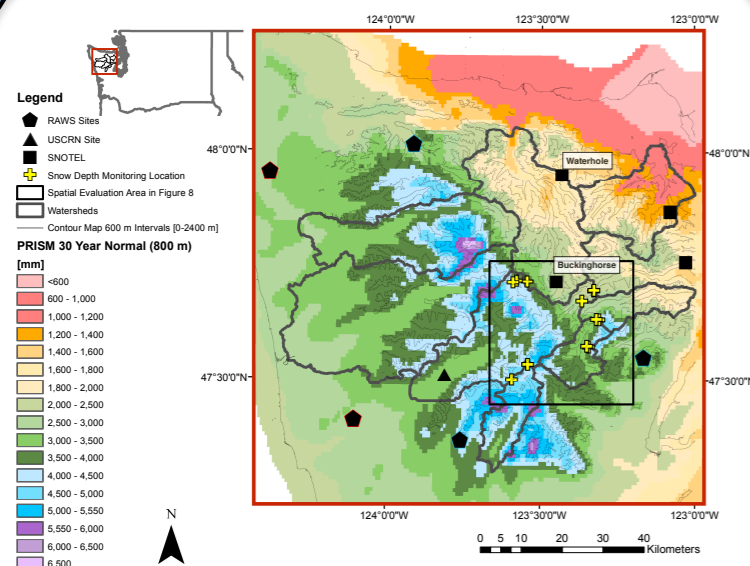


Figure 1: Independent snow-depth-monitoring locations used within this study relative to PRISM 30-yr annual precipitation averages on the Olympic Peninsula in northwest Washington State.

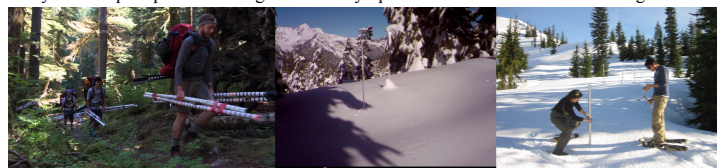


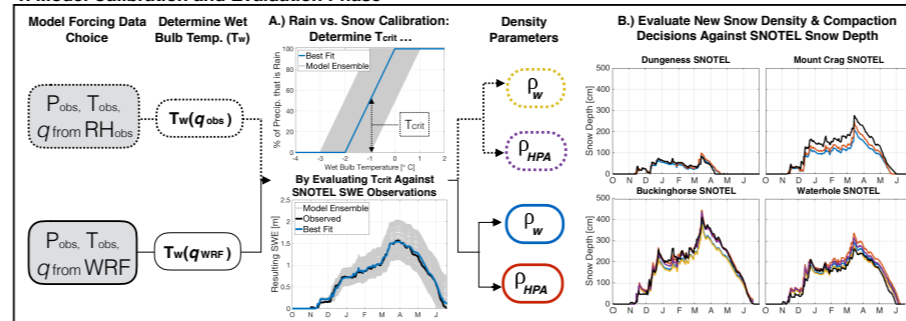
Figure 2: Left: Deploying snow depth poles, cameras, temp/RH sensors. Middle: Resulting time-lapse image from January. Right: Collecting snow density observations (Feb./March)

Methods: Rain vs. Snow Partitioning of Precip

We first calibrated SUMMA at the available SNOTEL sites using observed precipitation. We adjusted the precipitation partitioning parameters so that the model was unbiased for SWE from the start of the season until peak SWE. Forty percent of the winter precipitation fell between -1 and 2°C making rain vs. snow partitioning the most critical model parameterization in the Olympic Mountains. We used a calibrated wet-bulb-temperature based method and used output from WRF's microphysical scheme to partition rain vs. snow.

- **PRISM** simulations were only dependent on using the wet-bulb-temperature based method for partitioning.
- **WRF** used both the wet-bulb-temperature method (**WRFLP**) as well as the microphysical scheme output (**WRFMPP**).
- **WRF_{Full}** used all hydrologic model forcing data from WRF while other simulations used closely evaluated empirical methods (SW & LW) and nearby observations (T, RH, U).

1. Model Calibration and Evaluation Phase



2. Frozen Precipitation Evaluation Phase

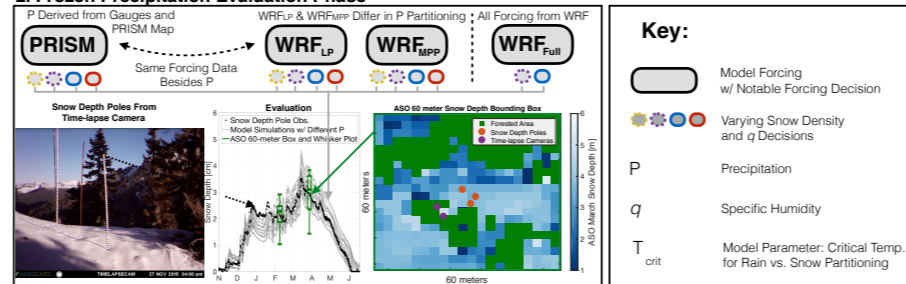


Figure 3: Conceptual figure of the overarching methodology with two phases: 1) the calibration of the T_{crit} model parameter for rain vs snow calibration (using SWE observations) and modeled snow depth evaluation against the four available SNOTEL sites (black line) and 2) evaluating simulations of snow depth and SWE from different precipitation estimates against OLYMPEX snow depth and SWE observations (snow depth poles and the median of an ASO 60-m bounding box—converted to SWE using snow course observations). ASO is the Airborne Snow Observatory (lidar). ρ_{HPA} and ρ_w reference Hedstrom and Pomeroy (1998) and Wayand et al. (2016) snow density modeling decisions

Results: Annual Differences

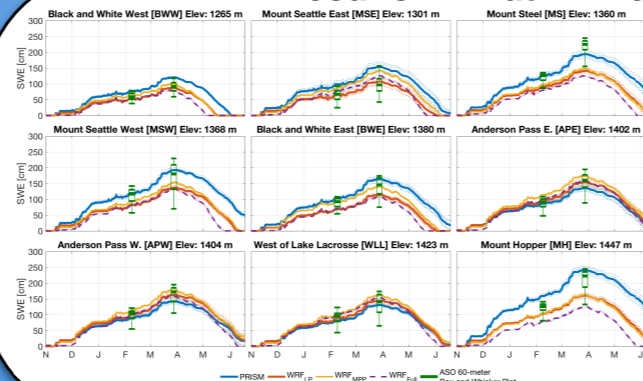


Figure 4: SWE simulations at 9 of 12 independent snow monitoring sites

Simulations diverged based on their source of precipitation (PRISM and WRFLP) and based on how the precipitation was partitioned (WRFLP and WRFMPP). WRFMPP simulated SWE with similar skill to PRISM, as they were both generally unbiased and had similar mean absolute differences. WRFLP was generally biased low, with a mean difference in SWE across all sites of -33 cm (-21%), which was outside the snow model's 95% confidence interval.



Results: OLYMPEX Intensive Obs. Period

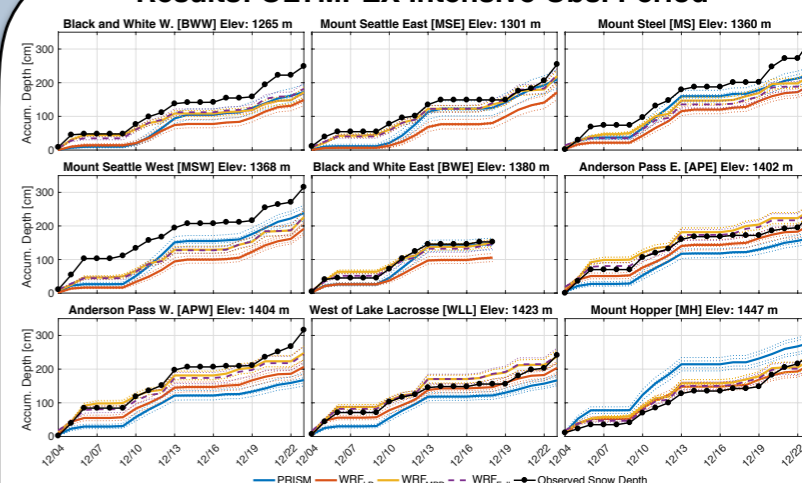


Figure 5: Accumulated snow depth between 4 and 23 December 2015 at 9 of 12 independent snow monitoring sites

Considering just December, when the Olympic Mountains received most of its snow (2–3 m of accumulated snow depth),

- WRFMPP had the smallest mean difference (-15%) and mean absolute difference, but generally under-accumulated. Nearly identical results were found for WRF_{Full}
- Temperature-based threshold methods led to errors in simulations over shorter time periods. For instance, observations showed that during the 4–6 December 2015 period, snowfall increased, while PRISM and WRFLP simulations generally stopped accumulating after 5 Dec.

Results: Spatial Distribution of Errors

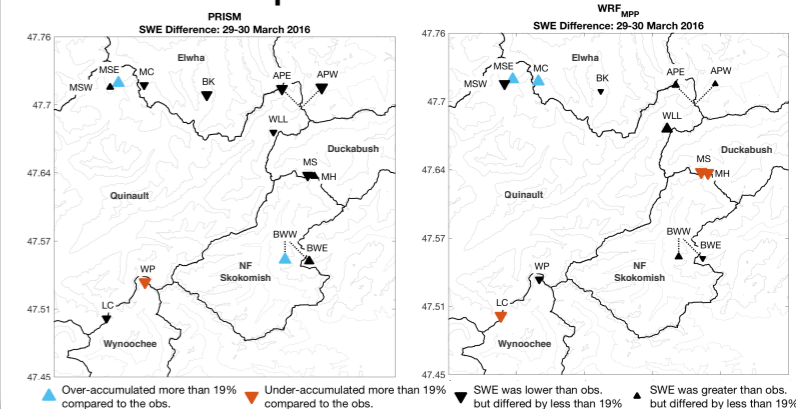


Figure 6: Percent errors of modeled SWE compare to median value from March ASO flight. Black triangles are scaled based on their error.

- No set of model simulations had errors that resulted in a definitive spatial pattern.
- We speculate that PRISM's annual average precipitation values are too low in the southern Elwha Watershed (MC, BK) and in the Eastern Quinault (APE, APW, WLL).

Conclusions

When SUMMA used WRF precipitation with a calibrated, wet-bulb-temperature-based method for partitioning rain vs. snow, its estimation of near-peak SWE was biased low by 21% on average. However, when SUMMA was allowed to partition WRF total precipitation into rain and snow based on output from WRF's microphysical scheme (WRF_{MPP}), simulations of snow depth and SWE were near equal to or better than simulations that used PRISM-derived precipitation with the calibrated partitioning method. Over all sites, WRF_{MPP} and simulations that used PRISM-derived precipitation had unbiased estimates of near-peak SWE, but both simulated significant absolute errors at a few locations.